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INT CL^5 F01N 1/02 1/20 1/22, F16L 55/033, G10K 11/16
Online databases: WPI

(54) **Variable cavity resonator**

(57) In a cavity resonator 402 having a variable resonance frequency, a constantly high sound-absorbing effect is achieved over the entire resonance adjustment range by also simultaneously adjusting, with the length, the cross-sectional area of the resonator neck 408 in accordance with an appropriately selected resonance/flow impedance relationship and, additionally, compensating the selfdamping of the resonator, for example with the aid of a heating device 432 arranged in the resonator neck 408.

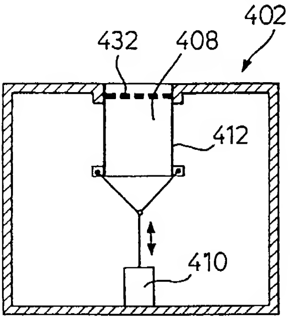

FIG. 5

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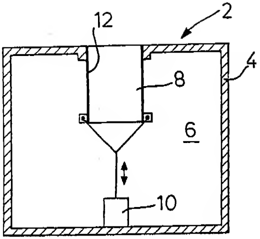

FIG. 1a

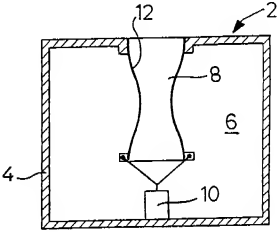

FIG. 1b

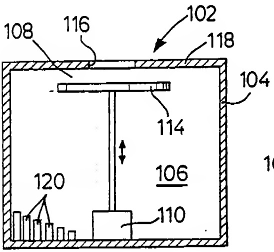

FIG. 2a

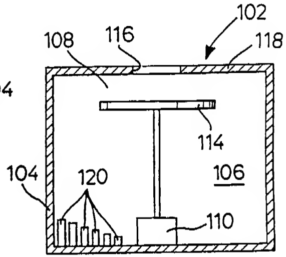

FIG. 2b

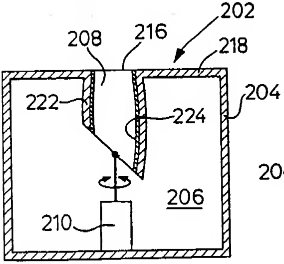

FIG. 3a

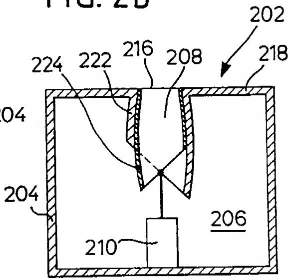

FIG. 3b

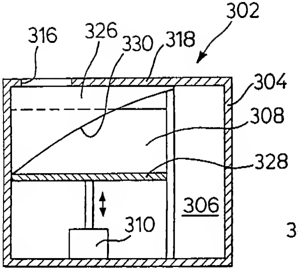

FIG. 4a

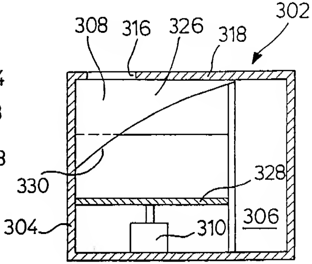

FIG. 4b

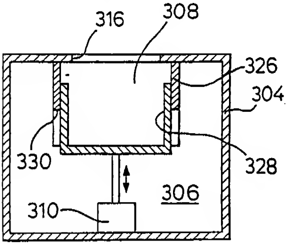

FIG. 4c

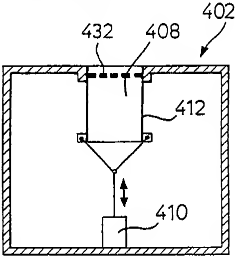

FIG. 5

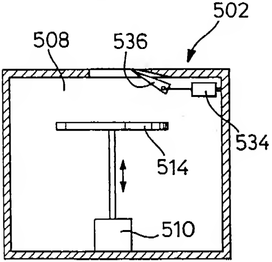

FIG. 6

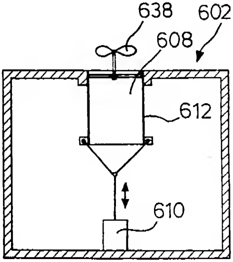

FIG. 7

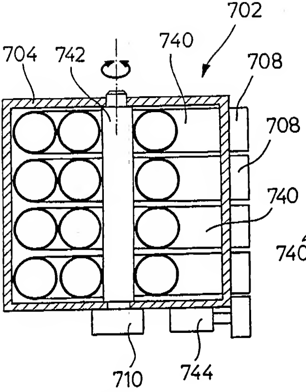

FIG. 8a

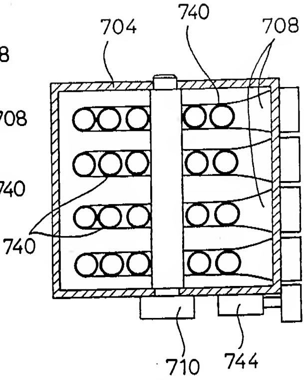

FIG. 8b

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Cavity resonator

The invention relates to a cavity resonator for reducing the emission and intromission of periodic noise of variable working frequency, in particular for reducing the noise of a piston engine.

Patent DE 33 00 499 A1 discloses a cavity resonator of this type in the form of a Helmholtz resonator having a variable resonance frequency which can be matched to the working frequency of the noise source by volumetric adjustment of the resonator cavity. However, such a resonator requires an unfavourably large installation space, of which only a small fraction can be used as cavity volume depending on the working frequency of the noise source, the more so as the resonance frequency varies only with the root of the effective resonator volume, is mechanically susceptible to trouble and has, above all, the disadvantage that the frequency adjustability is necessarily bound up with a worsening of the average sound-absorbing effect. Furthermore, a high grade noise reduction is achieved within the adjustment range only at a single working frequency, which is firmly prescribed as stipulated by the design.

The present invention seeks to configure a frequency-variable cavity resonator in such a way that a uniformly high sound-absorbing effect is to be achieved with a simple design over the entire resonance adjustment range.

According to the present invention there is provided a cavity resonator having a variable resonance frequency, wherein the flow impedance of the resonator is adjustable, in addition to the resonance frequency, as an independent variable.

In the cavity resonator according to embodiments of the invention, the respective resonance frequency and the flow impedance are no longer necessarily combined with one another in an invariant mutual dependence, but can be set

within broad limits independently of one another or in accordance with any desired function in such a way that the flow impedance over the entire resonance frequency adjustment range remains at a very low value and as a result a constantly high sound-absorbing effect of the cavity resonator can be achieved for periodic noise sources of changing working frequency.

In accordance with a further aspect of the invention which relates to a resonator of the Helmholtz type, the frequency adjustment and impedance adjustment are performed over the length and cross-section of the resonator neck, which has the substantial design advantage that the total installation space is always completely used as the effective resonator volume, the resonator has a fixed outer contour and the more sensitive adjusting mechanisms are situated protected in the resonator interior.

In a $\lambda/4$ resonator, the frequency adjustment and impedance adjustment are preferably effected by constructing said resonator to be variable both in terms of length and independently thereof - at least in part - in terms of cross-section.

As already mentioned, in accordance with the embodiments of the invention the flow impedance is adjusted in the resonance adjustment range to as low a value as possible, and this is expediently performed by means of a preselected frequency/flow impedance relationship, which in a further design simplification is integrated structurally into the cavity resonator.

In accordance with a further aspect of the invention, the resonator has as a further independent variable a variable self-damping which is reduced at the respective working point of the resonator down to a slight residual damping, as a result of which the sound-absorbing effect of the resonator, which is known to be inversely proportional to the self-damping in the case of resonance, can be further distinctly increased. A particularly simple design measure for compensating the resonator damping

consists in arranging in the inlet region of the resonator a heating device by means of which the loss factor is reduced up to shortly before the feedback point is reached at which the system goes into independent resonance vibrations in accordance with the principle of the Pinaud resonator or of the Rijke resonator. Preferably, a blade which is excited in a manner analogous to an organ pipe by the working medium flowing past is optionally arranged in the inlet region of the resonator in order to decrease the self-damping, as a result of which the loss factor of the resonator can be reduced in turn in a structurally simple and energy-saving way up to shortly before the feedback point is reached.

For the purpose of automatic matching to the respective noise situation, the resonator may contain in a particularly preferred way a control loop with sensors for determining the sound frequency to be damped and for generating an actuating signal which readjusts the resonance frequency and the flow impedance accordingly via the adjusting mechanism of the resonator.

In accordance with a further embodiment, variously tuned resonance tongues which are excited via structure-borne sound or air-borne sound and are arranged in the resonator interior are expediently used as sensors. The resonant tongue indicates the working frequency of the noise source, and its vibrational energy can be used for resonator control.

In a further preferred embodiment of the invention, finally, a wind wheel arranged in the inlet region of the resonator is provided for generating the natural current for the resonator adjustment, as a result of which, at high noise levels at which the sound particle velocity in the resonator neck becomes "palpably" high, use is made in an energy-saving fashion of the rectifier effect of the impelling movement which occurs at the inlet and outlet of the resonator neck due to the differing flow directions of the inlet flow and outlet flow.

The invention is now explained in more detail with the aid of a plurality of embodiments in conjunction with the drawings, in which in a strongly diagrammatic representation :

Figures 1a, 1b show an adjustable cavity resonator in the form of a Helmholtz resonator in two different working positions;

Figures 2a, 2b show a representation, corresponding to Figure 1, of a further embodiment of an adjustable Helmholtz resonator;

Figures 3a, 3b show a third embodiment of an adjustable Helmholtz resonator;

Figures 4a, 4b and 4c show a fourth embodiment of an adjustable Helmholtz resonator in two different working positions (Figures 4a and 4b) and in section (Figure 4c);

Figure 5 shows a resonator with a heating device in the inlet region for reducing the self-damping;

Figure 6 shows a resonator with an adjustable blade in the inlet region for reducing the self-damping;

Figure 7 shows a resonator with a wind wheel in the inlet region for generating natural current; and

Figures 8a, 8b show an adjustable $\lambda/4$ resonator in two different working positions.

Figure 1 shows an adjustable cavity resonator in the form of a Helmholtz resonator 2, consisting of a resonator housing 4 with an air-filled interior 6. The resonator neck 8 is designed by means of a control device 10 arranged in the resonator interior 6 so that it can be varied in terms both of its length and of its cross-section, and is formed by a flexible tube 12 which in the case of a change in length simultaneously experiences a specific change in cross-section, it being the case that due to the selected elasticity behaviour of the flexible tube 12 the

length/cross-section relationship is variable in a wide range and is prescribed such that the resonator 2 retains as low as possible a flow impedance irrespective of the resonance frequency readjusted via the control device 10 of the working frequency of the noise emitter.

The Helmholtz resonator in accordance with Figure 2, in which the components corresponding to the first embodiment are denoted by a reference numeral increased by 100, differs from said embodiment by a different construction of the adjustable resonator neck 108, which in this case is bounded by a disc 114 which can be axially displaced by means of the control device 110. Given a change in the spacing of the disc 114 with respect to the housing wall 118 provided with the resonator opening 116, there is a change in the air volume of the resonator neck 108, and thus in the resonance frequency of the resonator 102 and simultaneously in the cross-sectional area of the resonator neck 108 influencing the flow impedance. By means of an appropriate selection of the disc diameter and the shape of the disc, for example a conical or curved disc geometry instead of the planar geometry shown, it is possible, in turn, for the resonance frequency/flow impedance behaviour of the resonator 102 to be selected within wide limits so as to obtain a constantly low flow impedance over the entire resonance adjustment range. In addition, the resonator 102 contains a row of sheet-metal tongues 120 with stepped resonance frequencies. The excitation of the sheet-metal tongues 120 is performed by air-borne and/or by structure-borne sound. The respective working frequency of the noise source is determined via the resonant sheet-metal tongues 120, and an actuating signal is generated which via the control device 110 effects a corresponding readjustment of the resonance frequency and flow impedance.

In the embodiment in accordance with Figure 3, in which the individual components are denoted by a reference numeral increased by 200, the resonator neck 208 consists of an outer tube 222 fixed to the housing and a rotatable inner

tube 224 of the same shape, which in each case have bevelled ends and - at least in the region of the bevelled ends - circumferential surfaces which are inclined with respect to the axis of rotation and curved approximately convergently. By rotating the inner tube 224 between the end position shown in Figure 3a and that shown in Figure 3b, the length of the resonator neck 208, and thus the vibrating air mass of the resonator 202, can be varied. In this case, the flow impedance is also simultaneously adjusted in accordance with a function which is variably prescribed by the tapering of the tube ends and is, in turn, selected such that the resonator 202 has a constantly high sound-absorbing effect in the entire working range. Provided for the purpose of rotary positioning of the inner tube 224 is a rotary motor 210 which is controlled by an actuating signal proportional to the working frequency of the noise source.

In the Helmholtz resonator 302 in accordance with Figure 4, the resonator neck 308 consists of two transversely displaceably interlocking U-shaped profiled pieces 326 and 328, of which one - 326 - is arranged fixed to the housing and the other - 328 - is arranged in a height-adjustable fashion by means of the control device 310. The side cheeks 330 of the profiled piece 326 are bevelled in the direction of the outlet end of the resonator neck 308, so that given a height adjustment of the profiled piece 328 the effective length of the resonator neck 308 also varies simultaneously with the cross-sectional area. Any desired length/cross-section relationship of the resonator neck 308 can be selected by the shape of the bevel in such a way that the resonator 302 has a constantly high sound-absorbing effect in a wide resonance frequency adjustment range. Otherwise, the design and mode of functioning of the resonator 302 is the same as in the embodiments described above.

In accordance with Figure 5, there is a heatable grid 432 located in the resonator neck 408. Warming the entire resonator neck 408 also has the same effect.

According to the principle of the Pinaud tube or Rijke tube, the result is to achieve compensation of the natural resonator damping. The smaller the remaining residual damping is made, the lower is the effective flow resistance. However, a slight residual damping must be retained in order to avoid independent resonance vibrations of the resonator.

Figure 6 shows another possibility of influencing the flow resistance and thus also the flow impedance by changing the self-damping of the resonator. In this case, there is arranged in the region of the resonator neck 508 a blade 536 which can be adjusted by means of a servo motor 534 and onto which, when the resonator 502 is used, the working medium flowing past, for example the slip stream, is blown, and which thereby effects excitation of the resonator 502, by means of which the self-damping of the resonator is in turn reduced in a settable fashion to a residual damping. Otherwise, the design and mode of functioning of the resonators 402 and 502 are the same as in the case of the embodiments according to Figures 1 and 2, respectively.

Figure 7 shows a Helmholtz resonator 602 which has a wind wheel 638 at the outlet or - as shown - at the inlet end of the resonator neck 608. Because of the different profile of the inlet and outlet flow in the end regions of the resonator neck 608, a straightening of the flow is produced which is used by means of the wind wheel 638 for the purpose of the self-contained supply of energy to the resonator 602, that is to say to the control device 610 and the assigned control loop.

The embodiment according to Figure 8 relates to a $\lambda/4$ resonator 702 consisting of spirally wound flexible tubes 740. One flexible tube end is open and forms the resonator neck 708, while the other is closed and fastened to a drum 742 rotatably driven by means of the control device 710. By rotating the drum 742, changes are produced in the length and cross-section of the flexible tubes 740. Independently thereof, the cross-sectional area can be varied by twisting the flexible tubes 740 by means of a

second control device 744, and thus it is possible, in turn, to set a desired relationship between the resonance frequency and impedance of the resonator 702 in a manner analogous to the embodiments described above.

Claims

1. A cavity resonator having a variable resonance frequency, wherein the flow impedance of the resonator is adjustable, in addition to the resonance frequency, as an independent variable.

2. A cavity resonator according to Claim 1 in the form of a Helmholtz resonator, wherein the resonator has a resonator neck which is adjustable both in length and in cross-sectional area.

3. A cavity resonator according to Claim 1 in the form of a $\lambda/4$ resonator, wherein the resonator is constructed adjustably in terms both of length and, simultaneously, of cross-section.

4. A cavity resonator according to any one of the preceding claims, wherein the resonance frequency and the flow impedance are variable simultaneously according to a preselected function.

5. A cavity resonator according to any one of the preceding claims, wherein the resonator has a self-damping characteristic which is variable as an independent variable.

6. A cavity resonator according to Claim 5, wherein a heating device is arranged in the inlet region of the resonator in order to reduce the self-damping.

7. A cavity resonator according to Claim 5, wherein a blade which is excited by the working medium flowing past is arranged in the inlet region of the resonator in order to reduce the self-damping.

8. A cavity resonator according to any one of the preceding claims, including sensors for determining the

sound frequency to be damped and for generating an actuating signal which readjusts the resonance frequency and flow impedance accordingly.

9. A cavity resonator according to Claim 8, wherein resonance tongues which are arranged in the resonator interior and respond to different working frequencies are provided as sensors.

10. A cavity resonator according to any one of the preceding claims, wherein a wind wheel arranged in the inlet region of the resonator is provided for the energy supply of the resonator adjustment.

11. A cavity resonator having a variable resonance frequency, substantially as described herein with reference to and as illustrated in the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Application number
GB 9317492.8

Relevant Technical Fields (i) UK Cl (Ed.L) F1B (BFD) H4X (X2) (ii) Int Cl (Ed.5) F01N 1/02, 1/20, 1/22; F16L 55/033; G10K 11/16	Search Examiner P J EASTERFIELD
	Date of completion of Search 7 DECEMBER 93
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASES: WPI	Documents considered relevant following a search in respect of Claims :- 1 to 10

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Category	Identity of document and relevant passages	Relevant to claim(s)
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A	EP 0119634 A2 (NIPPONDENSO)	
A	US 4539947 A (SAWADA et al)	

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